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(54) **System for enhancing the performance of a CATV settop terminal**

(57) A system (10) for use with a CATV settop terminal (12) measures the input RF carrier signal power level at several frequencies within the CATV RF input bandwidth upon system power-up. The system utilises these measurements to selectively equalise and process the RF input signal depending upon the carrier frequency selected and the desired signal level to be input to the RF tuner. The system refines the signal level by specifically measuring the signal level of the selected carrier frequency. The system further improves RF tuner performance by dynamically limiting the bandwidth input to the RF tuner depending upon the selected carrier frequency.

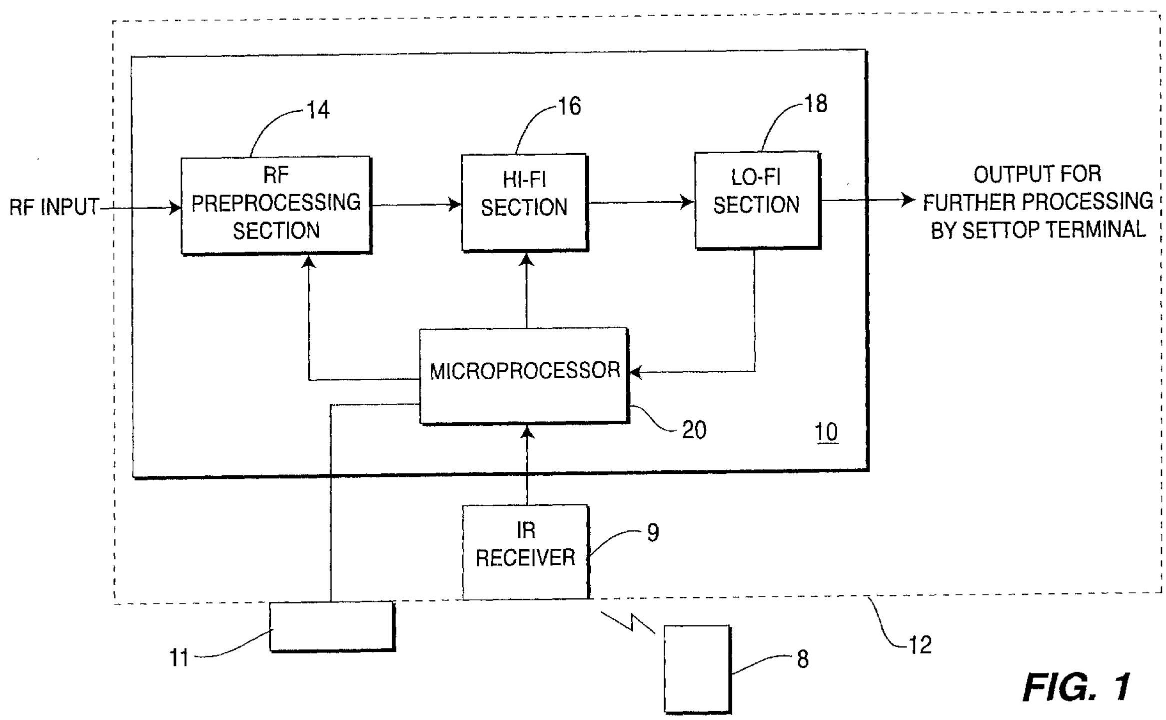

FIG. 1

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Description

This invention generally relates to cable television (CATV) communication systems. More particularly, the invention relates to a CATV settop terminal which includes a system for enhancing the performance of the RF tuner.

The CATV transmission spectrum typically comprises a bandwidth of frequencies up to 1000 MHz. During transmission of signals over the CATV network between the headend and the settop terminals, the higher frequencies experience greater attenuation than the lower frequencies. To compensate for the unequal attenuation, CATV network operators install devices throughout the CATV network to periodically equalize and amplify the signals as they are transmitted over the network. However, once the signal is output from the last active component in the transmission network, such as a line amplifier, no compensation for the unequal attenuation is provided. When line extenders are introduced or when a subscriber is located a long distance from the tap, large inequalities develop between the strength of signals at lower frequencies and those at higher frequencies. This degrades the performance of the RF tuner.

A second problem that reduces the performance of the RF tuner is the introduction of second and higher order distortions caused by the plurality of input carrier frequencies. As CATV network operators offer more channels over their networks, the bandwidth of the CATV network continues to expand. This results in an increase in the number of input carrier frequencies, which further degrades the performance of the RF tuner due to second and higher order distortions.

Accordingly, there exists a need for an inexpensive method to improve RF tuner performance in dual conversion CATV settop terminals.

The present invention comprises a system for use with a CATV settop terminal which measures the input RF carrier signal power level at several frequencies within the CATV RF input bandwidth upon system power-up. The system utilizes these measurements to selectively equalize and process the RF input signal depending upon the carrier frequency selected and the desired signal level to be input to the RF tuner. The system refines the signal level by specifically measuring the signal level of the selected carrier frequency. The system further improves RF tuner performance by dynamically limiting the bandwidth input to the RF tuner depending upon the selected carrier frequency.

Accordingly, it is an object of the present invention to provide a settop terminal with improved RF tuner performance.

Other objects and advantages will become apparent to those skilled in the art after reading the detailed description of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of the preferred embodiment of the settop terminal present invention;

Figure 2 is a detailed block diagram of the system of the present invention for enhancing the performance of a CATV settop terminal;

Figures 3A-3D are signal diagrams of the processing of the input RF spectrum;

Figure 4 is a diagram of the bandwidth of each individual filter within the band-switched filter;

Figure 5 is a flow diagram of the settop terminal in the setup mode; and

Figure 6 is a flow diagram of the settop terminal in the active mode.

The preferred embodiment will be described with reference to the drawing figures where like numerals represent like elements throughout.

Figure 1 is a block diagram of a system **10** made in accordance with the teachings of the present invention for enhancing RF tuner performance of a dual conversion settop terminal **12**. The settop terminal **12** is responsive to the selection of a particular channel by a consumer for viewing and listening. A consumer selects a desired channel using an input means, such as an infrared (IR) remote transmitter **8**, which outputs to an IR receiver **9**. Alternatively, a touchpad **11**, keyboard (not shown) or any other type of input device may be used. In response to the selection, the settop terminal **12** tunes to the RF carrier frequency associated with the selected channel and removes the carrier frequency. Audio and video content are then processed in a manner well known to those skilled in the art for viewing and listening by the consumer.

The system **10** generally comprises a radio frequency (RF) preprocessing section **14**, a high-intermediate frequency (HI-IF) section **16**, a low-intermediate frequency (LO-IF) section **18** and a microprocessor **20**. The RF preprocessing section **14** and the HI-IF section comprise what is typically referred to as a tuner **11**.

The RF preprocessing section **14** is coupled to the CATV transmission network via the RF input. The RF preprocessing section **14** accepts the entire RF input spectrum and preprocesses a select bandwidth of the spectrum as will be described in detail hereinafter. The HI-IF section **16** accepts the preprocessed bandwidth from the RF preprocessing section **14** and tunes to the carrier frequency corresponding to the channel selected by the consumer. The carrier frequency is upconverted, filtered and downconverted for output to the LO-IF section **18**.

The LO-IF **18** section further filters the IF signal, measures the signal level and removes the video and audio information from the IF signal. The baseband video and audio signal is forwarded for further processing by the settop terminal **12** in a manner that is well known to those skilled in the art. A control signal is also output by the LO-IF section **18** to the microprocessor **20**, which provides overall control of the RF preprocessing section **14** and the HI-IF section **16**.

The RF spectrum transmitted over the CATV transmission network is a wideband RF signal, extending from approximately 50 to 1,000 MHz. As the wideband signal is transmitted from the headend of the CATV system to the plurality of settop terminals, the frequencies at the lower end of the spectrum will experience different propagation loss rates than the frequencies at the higher end of the spectrum. At the input to a settop terminal **12**, therefore, the signal level of the lower frequencies may be much greater than the higher frequencies.

Referring to **Figure 2**, the RF preprocessing section **14** includes an equalizer **50**, a band-switched filter **52**, an automatic gain control (AGC) unit 54 and a lowpass filter **56**. The equalizer **50** compensates for the difference in the signal level between the lower frequencies and the higher frequencies by attenuating the frequencies having a higher signal level to the same level as the frequencies having a lower signal level. The result of equalization can be seen with reference to **Figures 3A** and **3B**. Prior to equalization, since the higher frequencies experience more attenuation in transmission than the lower frequencies, the higher frequencies have a lower signal level at the input of the equalizer **50** (**Figure 3A**). After equalization, whereby the signal level of the lower frequencies has been attenuated to the same signal level of the higher frequencies, the entire bandwidth has the same signal level (**Figure 3B**).

The output of the equalizer **50** is input into the band-switched filter **52**. Referring to **Figure 4**, the band-switched filter **52** comprises a plurality of individual band-pass filters **58**, **60**, **62**, **64** which are selectively activated, depending upon the channel, and thus carrier frequency, selected for viewing by the subscriber. Each band-pass filter **58**, **60**, **62**, **64** passes those frequencies falling within a selected portion of the RF spectrum and attenuates all frequencies falling outside of the passband. Although four band-pass filters **58**, **60**, **62**, **64** are shown in **Figure 4**, a greater or lesser number of filters may be employed, depending upon the application and number of available channels.

The effect of the band-switched filter **52** using the second filter **62** upon the output of the equalizer **50** will be explained with reference to **Figures 3B** and **3C**. The band-switched filter **52** passes only a portion of the input bandwidth. Accordingly, when the equalized output of **Figure 3B** is input into the band-switched filter **52**, an output having a reduced bandwidth as shown in **Figure 3C** is obtained. This has a beneficial impact on the performance of the HI-IF section **16**. Intermodulation distortion typically exists throughout the transmitted RF spectrum. As a portion of the RF spectrum is selected and further processed by a settop terminal, the intermodulation distortion increases. As a result of the band-limiting process, which reduces the bandwidth of the RF spectrum and the number of RF carrier frequencies seen at the input to the HI-IF section **16** of the tuner **11**, the increase in intermodulation distortion introduced by the settop terminal **12** is significantly reduced.

Referring again to **Figure 2**, the output of the band-switched filter **52** is input into the AGC unit **54** which further attenuates or amplifies the signal to a desired level. For example, as shown in **Figure 3C**, if the output from the band-switched filter **52** is at a level of -6dBmv and it is desired to have a signal level input to the HI-IF section **16** of -8dBmv, the signal level must be attenuated by an additional 2dBmv as shown in **Figure 3D**. The level input to the HI-IF section **16** may also be selectively adjusted to minimize distortions.

Referring again to **Figure 2**, the output from the AGC unit **54** is passed through a low-pass filter **56** and is then input to the HI-IF section **16**. The low-pass filter **56** band limits the input frequencies. As will be explained in detail hereinafter, the equalizer **50**, the band-switched filter **52** and the AGC unit **54** are dynamically controlled by the microprocessor **20** to optimize the performance of the RF tuner **11**.

The HI-IF section **16** generally comprises: 1) an upconverter **80**; 2) a HI-IF filter **86**; and 3) a downconverter **88**. The upconverter **80** comprises a first adjustable local oscillator **82** and an upconverter mixer **84**. The upconverter mixer **84** combines the signal output from the RF section **14** with the output of the first local oscillator **82** to upconvert the selected carrier frequency to a HI-IF frequency. Upconversion to the HI-IF frequency minimizes the interference to other television receivers by having the frequency of the first local oscillator **82** reside above any of the carrier frequencies. The HI-IF filter **86** filters the upconverted signal by providing rejection of other adjacent channel carriers outside the bandwidth of the filter **86**.

The downconverter **88** includes a downconverter mixer **92** and a second local oscillator **90**. The downconverter mixer **92** combines the HI-IF output signal with the output of the second adjustable local oscillator **90** to produce an output IF signal of 45.75 MHZ for the video carrier signal and 41.25 MHZ for the audio carrier signal to the LO-IF section **18**.

The LO-IF section **18** includes an IF filter **102** and a demodulator **104**. The IF filter **102** is a single channel filter which limits all unnecessary frequency components. The upper adjacent channel video carrier and lower adjacent channel sound carrier are attenuated at least 40-50 dB to eliminate visible disturbances in the picture. The output of the IF filter **102** is input into the demodulator **104** for video and sound IF carrier demodulation. The demodulator **104** measures the signal level of the video carrier and compares the video carrier level against a reference level to determine whether the video carrier level is too high or too low. If the video carrier level is at the proper level, (as determined by the reference level including tolerances), no further adjustments to the signal will be required. Accordingly, a baseband output signal **106**, including the video and audio information, are forwarded for further processing by the set-top terminal **12**. This processing includes descrambling and upconversion of the video and sound information to a second RF carrier for input into a television. The processing techniques are well known to those skilled in the art and a detailed description is outside the scope of this invention.

If the video carrier level as seen at the input to the demodulator **104** is too high or too low, the demodulator **104** outputs a control signal **108** to adjust the AGC level as determined by the AGC unit **54**. The control signal **108** may be input to the microprocessor **20** which controls the AGC unit **54** as shown in **Figure 2**. The control signal **108** is analyzed by the microprocessor **20**, which dynamically controls the equalizer **50**, the band-switched filter **52** and the AGC unit **54** as will be described in greater detail hereinafter. Alternatively, the demodulator **104** may output a separate control signal directly to the AGC unit **54** to override the control signal sent from the microprocessor **20** and to perform AGC level refinement.

When a channel is selected by a consumer, the selection is converted by the microprocessor **20** into a corresponding voltage. This voltage is used to adjust the frequency of the first local oscillator **82** to select the carrier frequency which corresponds to the channel selected by the consumer.

The present invention operates in two modes: 1) power-up mode **200**, and 2) active mode **400**. Referring to **Figure 5**, the operation of the present invention in the power-up mode **200** will be explained. Upon energizing the system **10**, the microprocessor **20** disables the equalizer **50** so that the RF input may be analyzed (**step 202**). The microprocessor 20 controls the HI-IF section **16** to tune to a high carrier frequency (x_2) within the CATV bandwidth (**step 204**). The carrier signal level (y_2) at that frequency is measured at the demodulator **104** and recorded by the microprocessor **20** (**step 206**). The microprocessor **20** then controls the HI-IF section **16** to tune to a low carrier frequency (x_1) (**step 208**). The carrier signal level (y_1) at that frequency is measured at the demodulator **104** and recorded by the microprocessor **20** (**step 210**). It should be noted that the carrier signals that are measured are signals that are used to transmit "actual" video and audio information. Accordingly, no "pilot carriers" are required.

Using the aforementioned measurements, the system slope (m) is calculated by the microprocessor **20** (**step 212**) using the following equation:

$$y_2 - y_1 = m(x_2 - x_1) \qquad \text{Equation (1)}$$

Assuming a linear slope (m) between the carrier signal level measured at the high and low frequencies:

$$\text{Equation (2)} \qquad y_2 = mx + b\ ,$$

the carrier signal level at any frequency may determined. In the preferred embodiment, the carrier signal level for a particular frequency is dynamically calculated as a channel is selected by the subscriber. Accordingly, when a channel is selected by a subscriber, the microprocessor **12** calculates the carrier signal level corresponding to that frequency and selectively adjusts the AGC unit **54** to provide the desired signal level for input into the HI-IF section **16**.

In a first alternative embodiment, the microprocessor **20** may precalculate the carrier signal level and a corresponding attenuation for each carrier frequency transmitted over the CATV network, and store these values in memory **21**, which is preferably non-volatile random access memory NVRAM.

In a second alternative embodiment, the slope may be set equal to zero and the actual level of each carrier may be measured. Whether the actual carrier signal level for each carrier frequency is measured, or the actual level for only several carrier frequencies is measured, the present technique provides a clear advantage over prior techniques which typically calculate an average for a plurality of carrier frequencies.

After the slope of the CATV network has been determined, the equalizer **50** is adjusted to equalize the frequencies over the entire bandwidth to provide a consistent carrier signal level output to the HI-IF section **16** (**step 214**). The power-up mode **200** may be entered periodically to ensure that the equalization, attenuation and gain control are optimally tailored to the current conditions of the CATV transmission network. Should the conditions of the CATV transmission network result in a change in the system slope, the equalizer **50** and the AGC unit **54** will be adjusted accordingly.

Operation of the system **10** in the active mode **400** will be explained with reference to **Figure 6**. When the consumer selects a desired channel (**step 402**) the microprocessor **20** performs several functions. First, the microprocessor **20** determines within which passband the selected carrier frequency will fall (**step 404**). The microprocessor **20** then sends a control instruction to the band-switched filter **52** to select the filter having the appropriate passband (**step 406**). The signal level for the selected carrier frequency is calculated and the level of amplification or attenuation by the AGC unit **54** is adjusted (**step 408**) to provide an output to the HI-IF section **16** at the desired level. The output of the first local oscillator **82** is controlled to select the desired carrier frequency for upconversion to the HI-IF bandwidth (**step 410**). The demodulator **104** measures the video carrier level (**step 412**) and compares this level against a reference level (**step 414**). If the video carrier level is the same as the predetermined level, (including tolerances), (**step 416**), no further adjustments to the signal will be required. The video and audio baseband signal is then output to the settop terminal video and audio processing section for further processing (**step 420**) in a manner well known to those skilled in art. If the video carrier level is not at the predetermined reference level (**step 416**), the demodulator **104** outputs a control signal to refine the AGC level (**step 418**). **Steps 412-418** are repeated until the carrier level is at the reference level.

The flexible architecture of the present invention may be utilized in an alternative embodiment to further increase the performance of the tuner **11**. For example, many settop terminals **12** contain a frequency channel map which describe the frequency placement of all the channels on the CATV network. Once the slope for the entire cable plant has been determined as aforementioned, the bandpass filter which corresponds to the tuned frequency may be activated. Knowing the channels which exist in the portion of bandwidth spanned by the passband filter, the system **10** can measure the signal level at a low channel within the bandwidth and a high channel within the bandwidth to further optimize the slope calculation for that bandwidth. This further improves performance of the tuner **11**.

Additionally, since the tuner **11** of the present invention can measure carrier signal level on a channel by channel basis, a more accurate algorithm to optimize slope across the RF input bandwidth may be utilized. For example, if the input carrier levels displayed a parabolic shape, the microprocessor **20** may be programmed to implement an algorithm which is the inverse of the parabolic shape, thereby resulting in a flat RF response which is input into the HI-IF section **16**.

Although the invention has been described in part by making detailed reference to certain specific embodiments, such details is intended to be instructive rather than restrictive. It will be appreciated by those skilled in the art that many variations may be made in the structure and mode of operation without departing from the spirit and scope of the invention as disclosed in the teachings herein.

Claims

1. A settop terminal for use on a CATV transmission network which transmits a plurality of channels over a transmission bandwidth, each channel for carrying information, the settop terminal comprising:

means for receiving said plurality of channels;
means for preprocessing said plurality of channels;
means for selecting one of said channels;
means for providing, from said selected channel, a baseband signal comprising said information for output to a display; and
means for measuring specific parameters of said selected channel; wherein one of said parameters comprises signal strength.

2. The settop terminal of claim 1 wherein said measuring means further comprises: means for controlling said selection means to select a channel at a lower frequency of said bandwidth and a channel at a higher frequency of said bandwidth; means for determining the signal strength at said lower and higher frequencies; and means for calculating a network path loss slope from said determination.

3. The settop terminal of claim 2 wherein said preprocessing means further comprises a filter for limiting the number of said channels which may be selected.

4. The settop terminal of claim 2 wherein said preprocessing means further comprises an equalizer, for attenuating the signal strength of a channel at a lower frequency to the same signal strength of a channel at a higher frequency.

5. The settop terminal of claim 4 wherein said preprocessing means further comprises an automatic gain control unit which adjusts the equalized signal strength level to a predetermined level.

6. The settop terminal of claim 5 wherein said measuring means further comprises means for controlling said automatic gain control unit in response to said calculation.

7. The settop terminal of claim 6 wherein said filter further comprises a selectable filter having:

a plurality of bandpass filters, each filter having a different passband; and
means for activating one of said bandpass filters in response to said selection means.

8. The settop terminal of claim 1 wherein said selection means further comprises:

an upconverter for mixing said selected channel with an upconversion frequency to provide a high intermediate frequency;
a filter for filtering said high intermediate frequency; and
a downconverter for mixing said high intermediate frequency with a downconversion frequency to provide a low intermediate frequency.

9. The settop terminal of claim 5 wherein said automatic gain control unit further includes means for attenuating said equalized signal strength level and means for amplifying said equalized signal strength level.

10. The settop terminal of claim 9 wherein said measuring means comprises a low intermediate frequency filter which filters said low intermediate frequency to attenuate adjacent channels and eliminate disturbances in said information.

11. A method for improving performance of a settop terminal for use on a CATV transmission network which transmits a plurality of channels over a transmission bandwidth, each channel carrying information, the method comprising:

receiving said plurality of channels;
preprocessing said plurality of channels;
selecting one of said channels;
providing, from said selected channel, a baseband signal comprising said information for output to a display; and
measuring specific parameters of said selected channel; wherein one of said parameters comprises signal strength.

12. The method of claim 11 wherein said measuring step includes:

controlling said selection means to select a channel at a lower frequency of said bandwidth and a channel at a higher frequency of said bandwidth,
determining the signal strength at said lower and higher frequencies; and
calculating a network path loss slope from said determination.

13. The method of claim 12 wherein said preprocessing steps further comprises limiting the number of said channels which may be selected.

14. The method of claim 12 wherein said preprocessing step further comprises attenuating the signal strength of a channel at said lower frequency to the same signal strength of a channel at said higher frequency.

15. The method of claim 14 wherein said preprocessing step further comprises adjusting the equalized signal strength level to a predetermined level.

16. The method of claim 15 wherein said measuring step further comprises controlling said adjustment in response to said calculation.

17. The method of claim 16 wherein said filter step comprises providing a selectable filter having a plurality of bandpass filters, each filter having a different passband; and activating one of said filters in response to said selection step.

18. The method of claim 11 wherein said selection step further comprises:

mixing said selected channel with an upconversion frequency to provide a high intermediate frequency;
filtering said high intermediate frequency; and
mixing said high intermediate frequency with a downconversion frequency to provide a low intermediate frequency.

19. The method of claim 18 wherein said measuring step further comprises filtering said low intermediate frequency to attenuate adjacent channels and eliminate disturbances in said information.

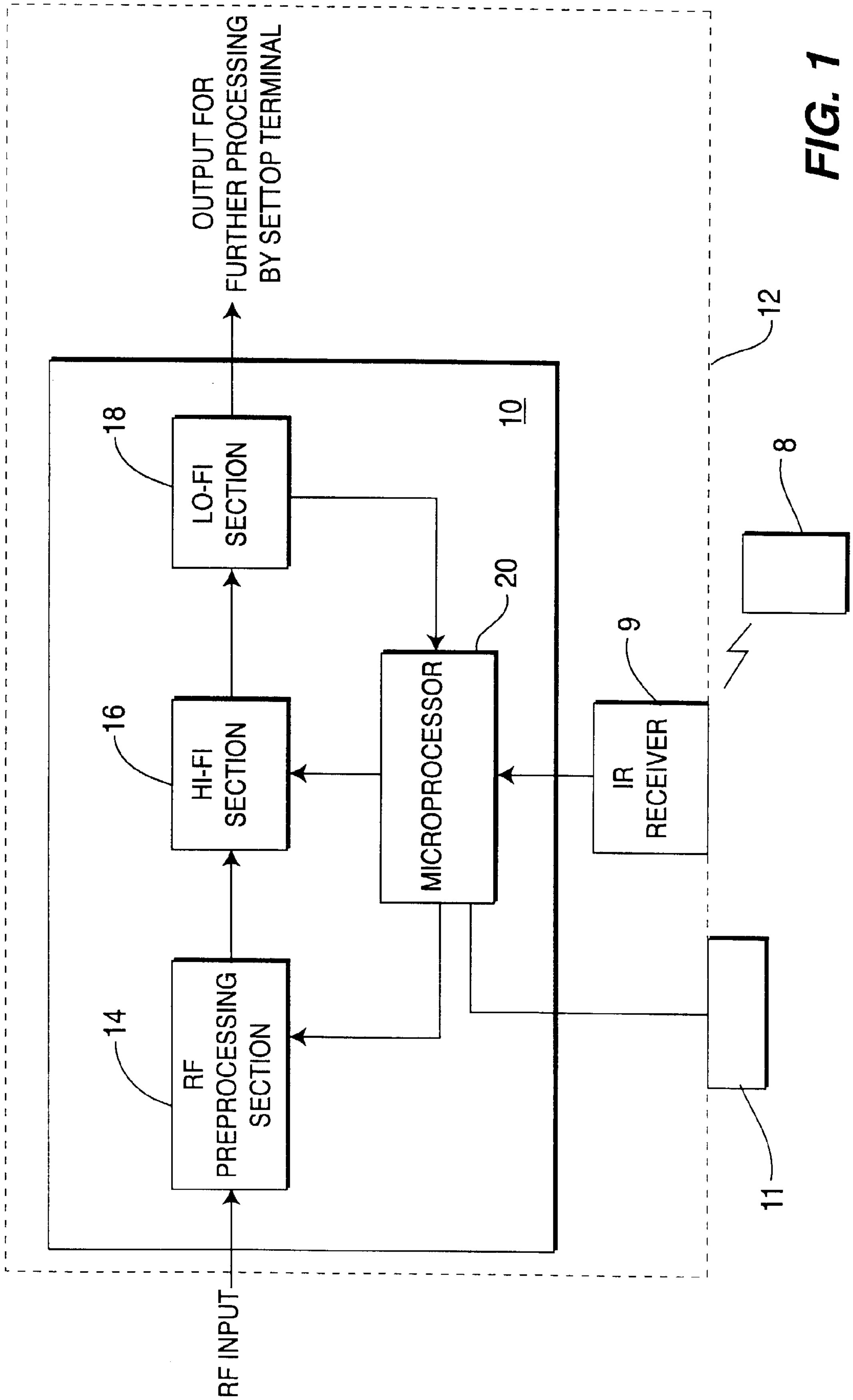
OUTPUT FOR
FURTHER PROCESSING
BY SETTOP TERMINAL
RF INPUT
RF
PREPROCESSING
SECTION
HI-FI
SECTION
LO-FI
SECTION
MICROPROCESSOR
IR
RECEIVER
14
16
18
20
10
12
9
8
11

FIG. 1

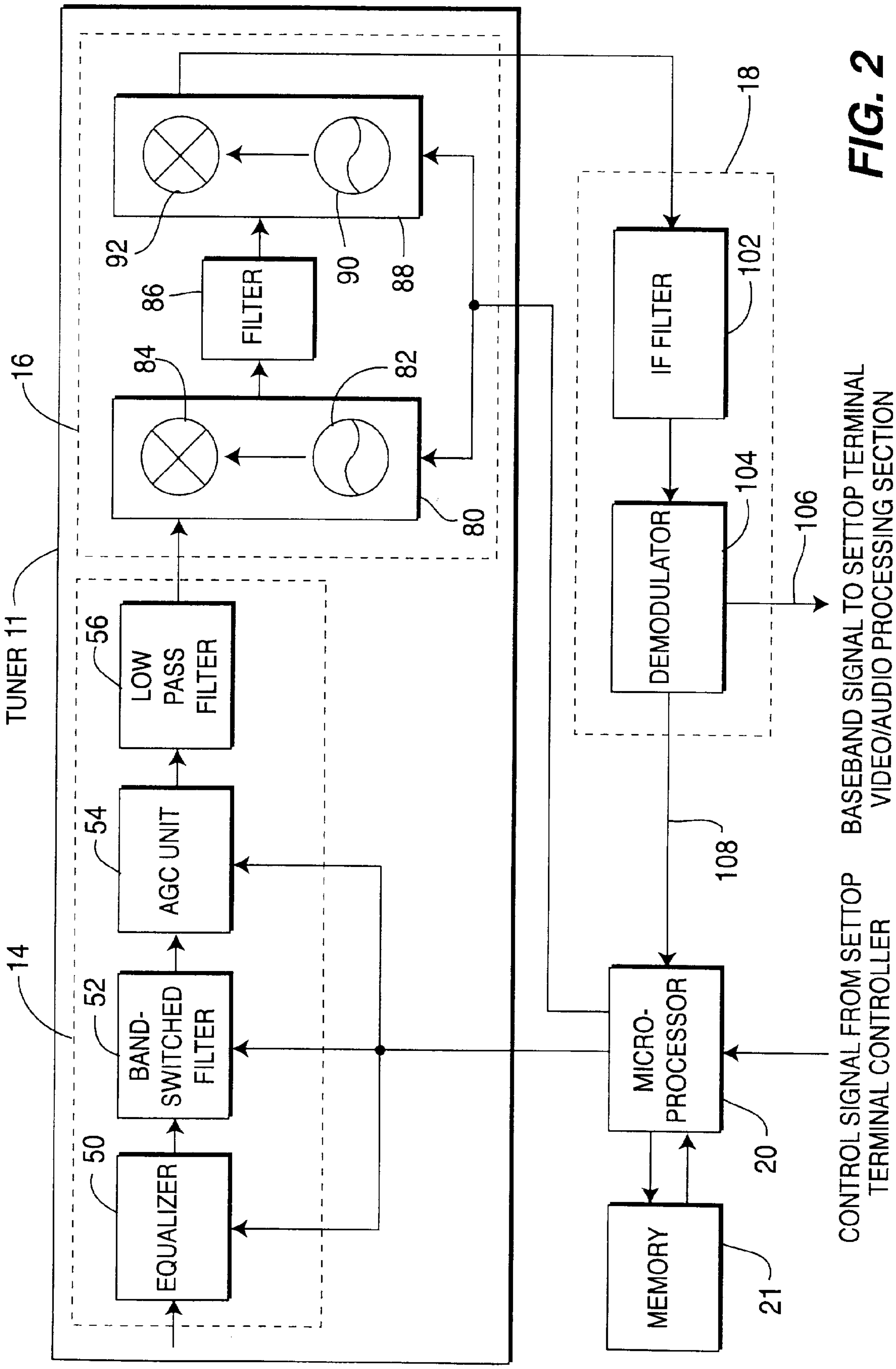
TUNER 11
14
16
18
EQUALIZER
50
BAND-SWITCHED FILTER
52
AGC UNIT
54
LOW PASS FILTER
56
80
82
84
FILTER
86
88
90
92
IF FILTER
102
DEMODULATOR
104
106
108
MICRO-PROCESSOR
20
MEMORY
21
BASEBAND SIGNAL TO SETTOP TERMINAL VIDEO/AUDIO PROCESSING SECTION
CONTROL SIGNAL FROM SETTOP TERMINAL CONTROLLER

FIG. 2

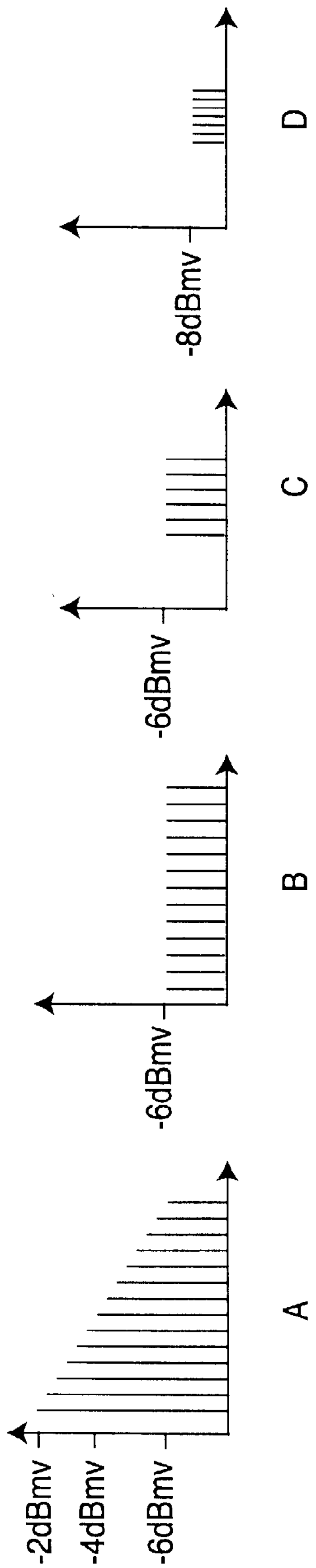

FIG. 3

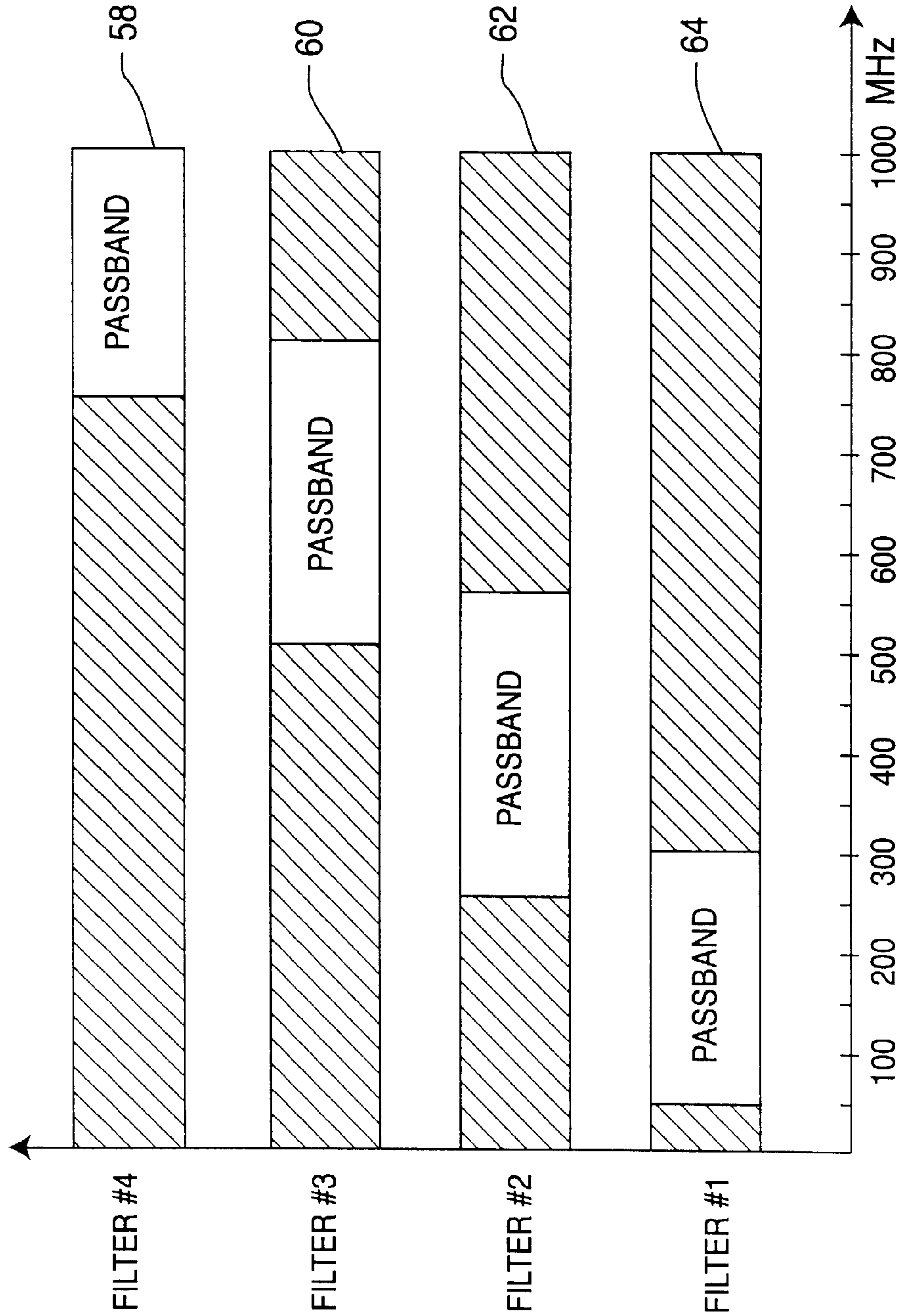
58
60
62
64
PASSBAND
PASSBAND
PASSBAND
PASSBAND
FILTER #4
FILTER #3
FILTER #2
FILTER #1
100
200
300
400
500
600
700
800
900
1000
MHz

FIG. 4

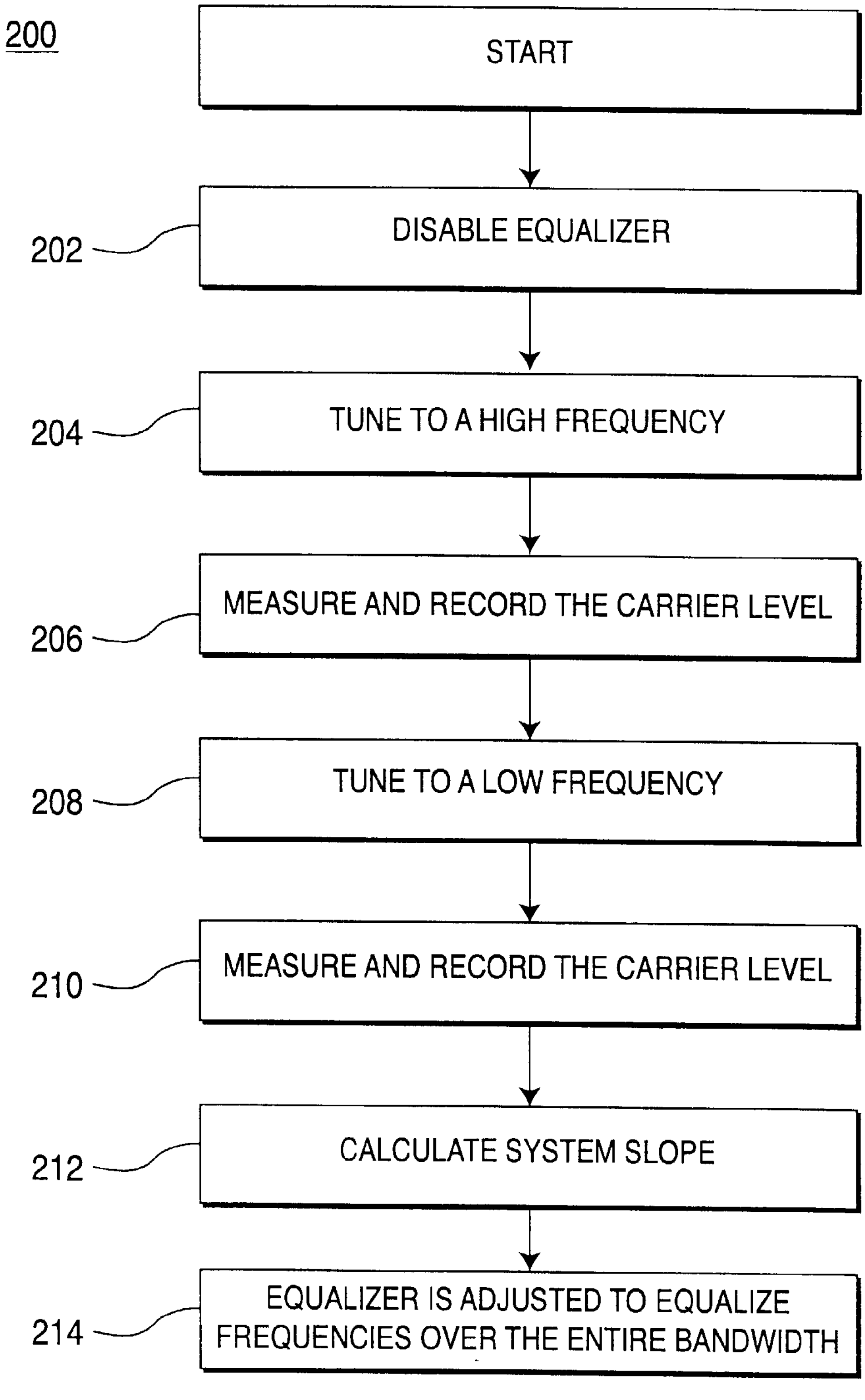
200
START
202
DISABLE EQUALIZER
204
TUNE TO A HIGH FREQUENCY
206
MEASURE AND RECORD THE CARRIER LEVEL
208
TUNE TO A LOW FREQUENCY
210
MEASURE AND RECORD THE CARRIER LEVEL
212
CALCULATE SYSTEM SLOPE
214
EQUALIZER IS ADJUSTED TO EQUALIZE FREQUENCIES OVER THE ENTIRE BANDWIDTH

FIG. 5

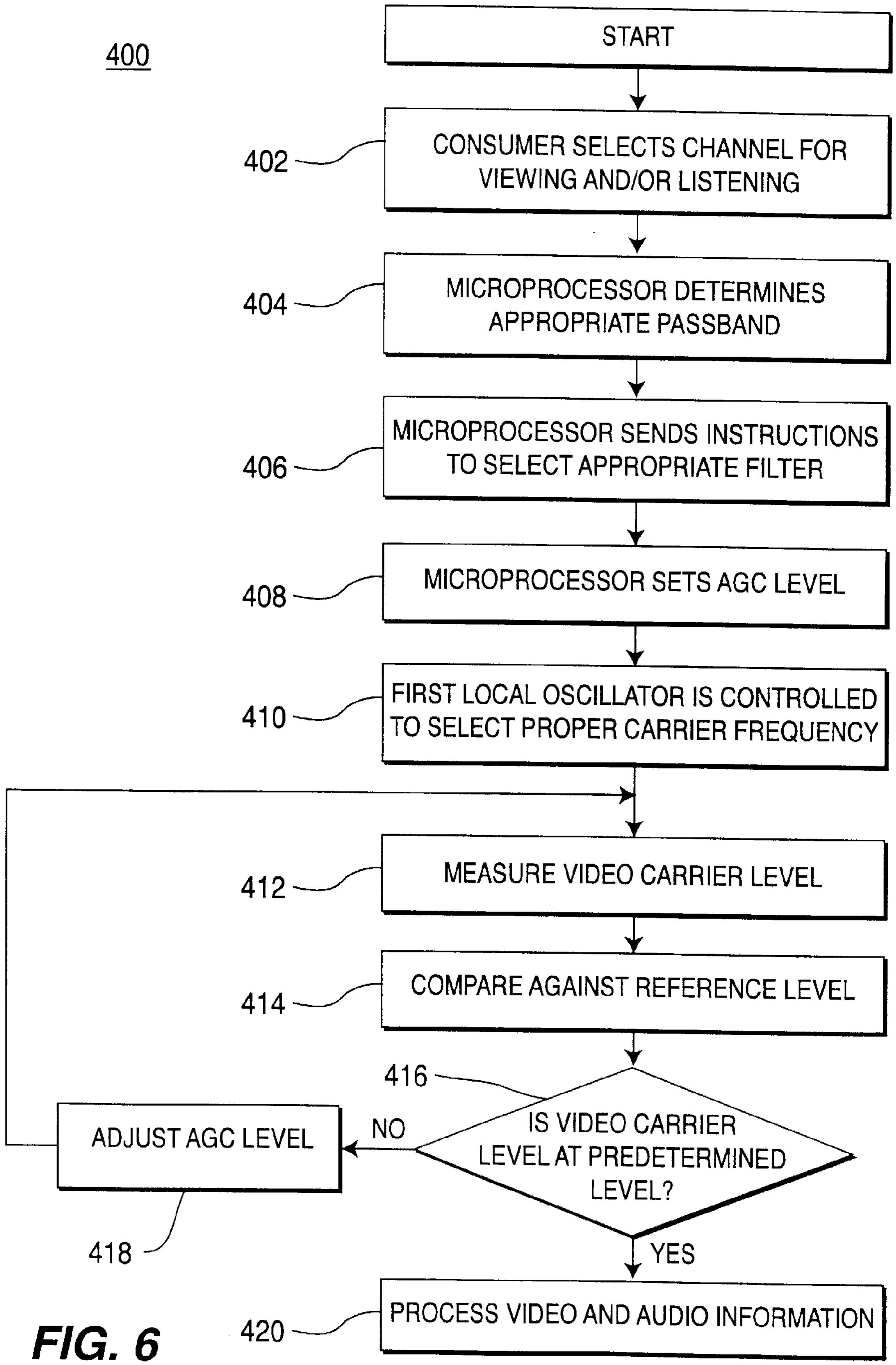
400
START
402
CONSUMER SELECTS CHANNEL FOR VIEWING AND/OR LISTENING
404
MICROPROCESSOR DETERMINES APPROPRIATE PASSBAND
406
MICROPROCESSOR SENDS INSTRUCTIONS TO SELECT APPROPRIATE FILTER
408
MICROPROCESSOR SETS AGC LEVEL
410
FIRST LOCAL OSCILLATOR IS CONTROLLED TO SELECT PROPER CARRIER FREQUENCY
412
MEASURE VIDEO CARRIER LEVEL
414
COMPARE AGAINST REFERENCE LEVEL
416
IS VIDEO CARRIER LEVEL AT PREDETERMINED LEVEL?
NO
ADJUST AGC LEVEL
418
YES
420
PROCESS VIDEO AND AUDIO INFORMATION

FIG. 6